Simulated Lumbar Minimally Invasive Surgery Educational Model With Didactic and Technical Components

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BACKGROUND: The learning and development of technical skills are paramount for neurosurgical trainees. External influences and a need for maximizing efficiency and proficiency have encouraged advancements in simulator-based learning models.

OBJECTIVE: To confirm the importance of establishing an educational curriculum for teaching minimally invasive techniques of pedicle screw placement using a computer-enhanced physical model of percutaneous pedicle screw placement with simultaneous didactic and technical components.

METHODS: A 2-hour educational curriculum was created to educate neurosurgical residents on anatomy, pathophysiology, and technical aspects associated with image-guided pedicle screw placement. Predidactic and postdidactic practical and written scores were analyzed and compared. Scores were calculated for each participant on the basis of the optimal pedicle screw starting point and trajectory for both fluoroscopy and computed tomographic navigation.

RESULTS: Eight trainees participated in this module. Average mean scores on the written didactic test improved from 78% to 100%. The technical component scores for fluoroscopic guidance improved from 58.8 to 52.9. Technical score for computed tomography—navigated guidance also improved from 28.3 to 26.6.

CONCLUSION: Didactic and technical quantitative scores with a simulator-based educational curriculum improved objectively measured resident performance. A minimally invasive spine simulation model and curriculum may serve a valuable function in the education of neurosurgical residents and outcomes for patients.

KEY WORDS: Lumbar, Minimally invasive, Resident training, Simulator, Spine surgery

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Maximizing surgical technical ability is a critical priority for educators of surgical trainees. However, opportunities to develop these skills are increasingly limited because of work-hour restrictions, the increasing cost of operating room time, and ethical concerns for patient safety.[1] These factors have fostered educational environments for surgical residents based outside the operating room. Using predeveloped pathways and models established by the aviation industry, surgical specialties are aiming to improve safety and expertise through mimicking real-world scenarios.[2]

Simulation models may have utility particularly in the neurosurgical realm. For example, placement of lumbar pedicle screws using minimally invasive techniques requires a strong working knowledge of 3-dimensional spinal anatomy and the use of radiologic technology. Through repetitive use of a physical model of percutaneous pedicle screw placement, we propose to objectively measure the competence of neurosurgical residents and to gauge improvement with this surgical technique. The goal of the model is to help improve efficiency and proficiency in placing pedicle screws in a real-world simulated situation that might typically be seen in the operating room. Attaining a level of fundamental competence using

ABBREVIATION: CNS, Congress of Neurological Surgeons

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such a simulator may help simultaneously improve technical skills of trainees and operative outcomes without jeopardizing the safety of the patients.

METHODS

A 120-minute module made up of both written and practical tutorials was developed through a consensus and Adelphi process among leaders in the spine community. Participating residents first completed a written pretest of 12 elementary questions on basic spinal anatomy and pathophysiology. Residents also performed a technical pretest in which they chose the ideal starting point and trajectory for placement of percutaneous pedicle screws at L4 and L5 using both fluoroscopy and computed tomographic (CT) navigation.

These baseline assessments were then followed by a didactic session consisting of a 15-minute PowerPoint presentation focusing on lumbar spine anatomy and operative technique. Participants learned to identify anatomic parts of the spine and their relationship with vital surrounding structures through the presentation and through direct interaction with the supervisors. They were instructed on how to obtain appropriate fluoroscopic images necessary for percutaneous screw placement while limiting themselves and coworkers to radiation exposure.[3,4] Lessons and principles from the written pretest and foundations for screw placement were explained to the trainees. A clinical case presentation focusing on the indications for this procedure was given.

The model of percutaneous pedicle screw placement was developed with the help of Medtronic Surgical Technologies (Figure 1). A computerized scan of a physical sawbone model of a lumbar spine with L4-5 spondylolisthesis was made to re-create fluoroscopic images and CT images for simulated navigation (see **Video 1, Supplemental Digital Content 1,** http://youtu.be/oeDSw0yxzP0, which describes the setup, components, and use of the simulator model). Ideal starting points and trajectories were chosen by senior spine fellowship—trained neurosurgical faculty and confirmed by 3 individuals (Figure 2). In both the fluoroscopic and the CT navigation model, the participants then chose starting points and trajectories for lumbar pedicle screws, which were graded in comparison to the ideal markings (Figures 2 and 3). For the fluoroscopic model, scores were calculated on the basis of fluoroscopy time, number of fluoroscopic shots required, and proximity to the ideal starting point and trajectory. In the CT navigation setting, scores were calculated on the basis of time and proximity to ideal starting point and trajectory. Scores on the practical simulator were graded on a scale from 1 to 300, with a lower number representing a better score.

FIGURE 1. *Medtronic Surgical Technologies system setup.*

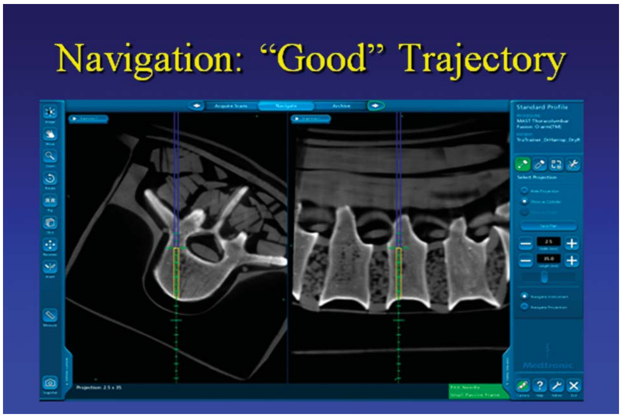

FIGURE 2. *Ideal starting point and trajectory as seen on the computed tomographic navigation.*

The participants subsequently were reassessed with a written posttest (same questions as in the pretest administered in a different order) and a practical posttest in which they reattempted identification of the trajectory of pedicle screws using fluoroscopy and CT navigation. The residents obtained feedback from the faculty through review of incorrect responses, through objective automated score reporting from the simulator model, and through a debriefing session at the completion of the module.

RESULTS

This minimally invasive simulator model for percutaneous pedicle screw placement was used at the 2012 Congress of Neurological Surgeons (CNS) simulator course held in Chicago, Illinois. Eight participants with different levels of training participated in the 2-hour module. All participants were male. Participant expertise varied from no operative experience to having completed training and performed minimally invasive spine techniques in clinical practice.

The mean written pretest score among participants was 78%, ranging from 67% (8 of 12) to 83% (10 of 12). All 8 participants improved to a score of 100% after the didactic session, with the greatest change in score being 33% (8 of 12 to 12 of 12).

Initially, fluoroscopy-guided screws were attempted at the L4 and L5 levels. Among the 16 attempts (1 attempt at each level performed by all 8 participants), pretest scores ranged from 29.6 to 128, with a mean of 58.8 ± 26.2. Posttest scores ranged from 19.8 to 117, with a mean score of 52.9 ± 22.7 (P = .47), indicating a trend of improvement. Mean fluoroscopy time also improved from 193 ± 161 to 141 ± 104 seconds per screw (P = .40), a decrease of 52 seconds or 26.9%. The mean number of fluoroscopic shots required to localize and place the percutaneous screw decreased from 12.8 ± 7 to 11.7 ± 5 shots (P = .44).

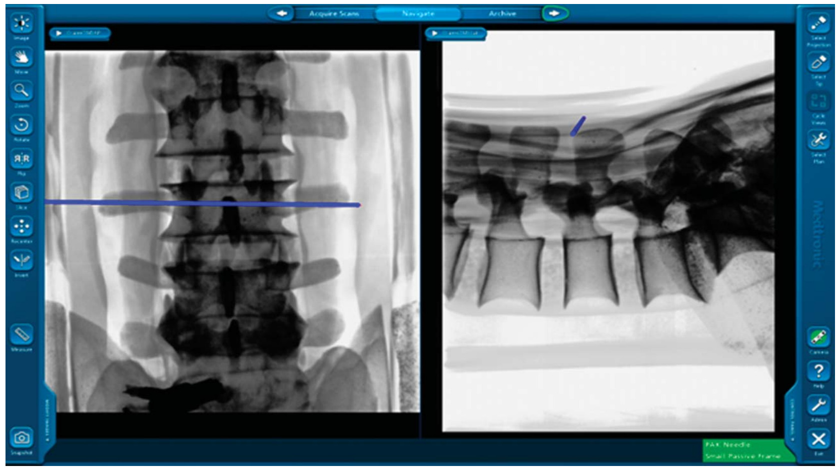

FIGURE 3. *Fluoroscopic image demonstrating attempted localization of appropriate lumbar level.*

CT-navigated percutaneous screws were also attempted at the L4 and L5 levels. Although the time required for finding the screw trajectory remained similar on the pretest and posttest (111.5 and 112.8 seconds, respectively), overall scores accounting for both time and accuracy showed a trend toward improvement (28.3 ± 11.8 to 26.6 ± 12.8; P = .42).

DISCUSSION

In an attempt to augment the training received by surgical residents, simulators including both physical and virtual reality models have been developed. Through this ex vivo mode of learning, trainees are able to hone and improve their operative skills outside the operating room. Supplementing the traditional training, simulator models may improve surgical skills and techniques. Both physical and virtual reality laparoscopic models have been successfully incorporated into training programs for general surgery residents. The goals of these simulators are to establish objective criteria by which surgeons are assessed and to help obtain a baseline level of technical ability before complex techniques are attempted on actual patients.[5] Recent systematic studies have shown that this type of ex vivo or simulated training program improves outcomes in the operating room, proving to be a valuable educational tool for residents looking for additional experience given their time and real-world constraints.[6-10] The CNS has remained at the forefront of this movement, with the development of an educational program for different aspects of neurosurgery. With the assistance of Medtronic Surgical Technologies, a curriculum for minimally invasive pedicle screw placement in the lumbar spine was created.

Through the use of this educational tool in the CNS 2012 course in Chicago, advantages of such a simulator were illustrated. Trainees who use this type of simulator are able to perform a self-assessment in the form of a written pretest and a practical examination. Evaluation of performance on the written and technical components provided immediate objective feedback on potential areas for improvement that can be targeted during the didactic portion of the module. Even in the absence of senior neurosurgical direction, the objective computerized scoring allows trainees to practice surgical skills and still obtain meaningful feedback before entering the operating room.

In this limited sample size (n = 8), improvement was demonstrated in both the written and practical components (Table). The module format, composed of pretest and posttests with a reproducible didactic session, allowed a standardized lesson for trainees. With future iterations and more participants, we hope that the objectivity of the assessments and the reproducibility of the module will make it easy to produce similar results with less variability among participants and will validate our metrics and educational model. Whether improvement on this simulator translates into better patient outcomes also has to be studied.

In the CNS 2012 session, the participants also used the models to physically place a pedicle screw into the sawbone model using the Jamshidi needle and minimally invasive tap and screw. By

TABLE. Results

	Pretest	Posttest
Fluoroscopy		
Overall score	58.8 ± 26.2	52.9 ± 22.7
Time under fluoroscopy, s	193 ± 161	141 ± 104
Fluoroscopic shots, n	12.8 ± 7	11.7 ± 5
Computed tomographic navigation		
Overall score	28.3 ± 11.7	26.6 ± 12.8
Time, s	111.5	112.8
Written examination, %	78 ± 6	100

disassembling the model after the attempted screw placement, participants could evaluate for any cortical breaches related to their pedicle screw placement. This hands-on 3-dimensional evaluation provided yet another facet to the educational experience and helped residents understand complex anatomy and basic surgical principles.

Future directions include creating individualized sawbone constructs modeled after CT images of real-time patients. This would provide the residents the opportunity to simulate an operation on a unique model before entering the operating room the next day. Simulators like this can move beyond just training technical skills. For example, they might help train operating room teams for situations that may be encountered in the operative theater, including complications that require communication among anesthesia, nursing staff, and the surgeon. Courses for anesthesia crisis resource management have attempted training in this way.[11,12] Future iterations may also focus on rod design and rod placement, as well as simulation of technical complications, including pedicle breach, inadvertent wire misplacement, or hardware malfunction. Validation of our educational tool and use in training now for residents may work to produce better and safer neurosurgeons for our future.

CONCLUSION

This simulator-based educational curriculum illustrated that residents showed objective improvement after both lecture tutorial and practical hands-on simulator experience with minimally invasive pedicle screw placement. With results from future participation, this method of simulator training may assist in making neurosurgical residents technically better in a more efficient manner.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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